Ozone Levels Near Lake Michigan

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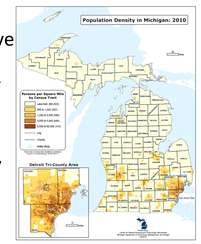
Introduction

Ozone (O_3)is a secondary pollutant formed through a series of photochemical reactions involving oxides of nitrogen (NOx) and volatile organic compounds (VOCs). Major sources of VOCs include automobile emissions; gasoline and oil transfer; incompletely burned coal or wood; and industrial use of paint solvents, degreasing agents, and cleaning fluids[1]. Sources of NOx include fuel combustion in automobiles and power plants; and processes used in chemical plants[1].

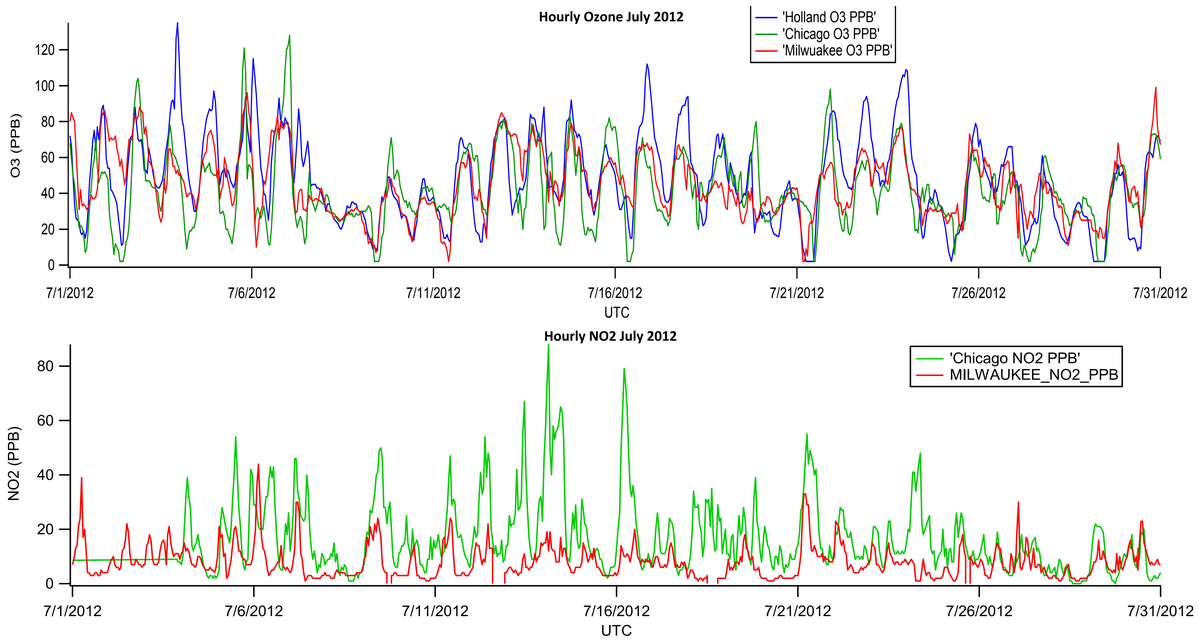


Abnormally high concentrations of O_3 have been observed in rural locations on the shores of western Michigan at a distance of hundreds of kilometers from major anthropogenic sources. In fact, western Michigan is largely devoid of major industry and major population centers and yet has experienced high summer ozone levels for more than a decade.

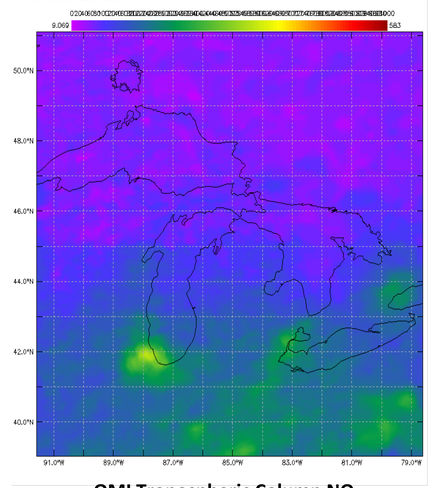
In a study by Lennartson, it was supported that the high ozone levels are due to the transport of ozone from industrial centers located across Lake Michigan, in particular, Milwaukee and Chicago[2]. There is also some evidence that Lake Michigan would provide an excellent corridor for the production of ozone[3].

This study compared ozone levels in Holland, Michigan to those in Chicago and Milwaukee for the summer of 2012. The summer of 2012 was of interest showing a number of days with elevated levels of ozone. Holland Michigan was chosen due to its proximity to the other two cities. For dates of particular interest NO_2 levels are investigated. Back trajectories of air masses show transport of NO_2 and ozone.

Ozone July 2012

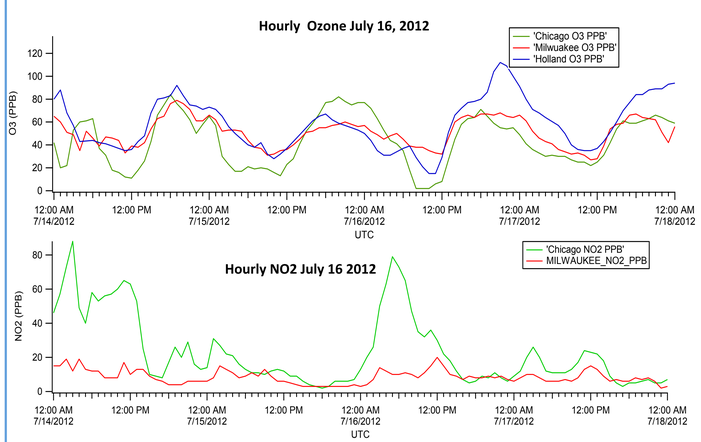


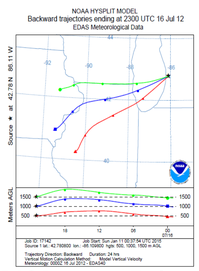
Shown left are the graphs of the hourly ozone levels for July 2012 in Holland, Chicago and Milwaukee. NO_2 levels are provided for Chicago and Milwaukee but no NO_2 ground station data was available in Holland. However, OMI satellite data was available and is shown below.
Note that the ozone levels in the three cities show very similar diurnal activity. Holland can have ozone levels up to 50ppb, even higher than the two industrial centers. Note that both industrial centers show NO_2 available for ozone production. The OMI satellite data shows the concentrations of NO_2 over the Great Lakes.



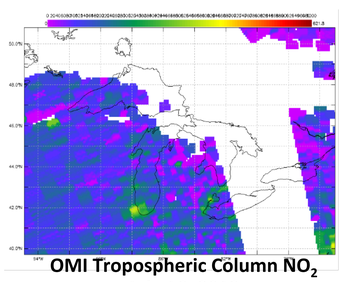
OMI Tropospheric Column NO_2 July 2012

July 16,2012 Ozone Event



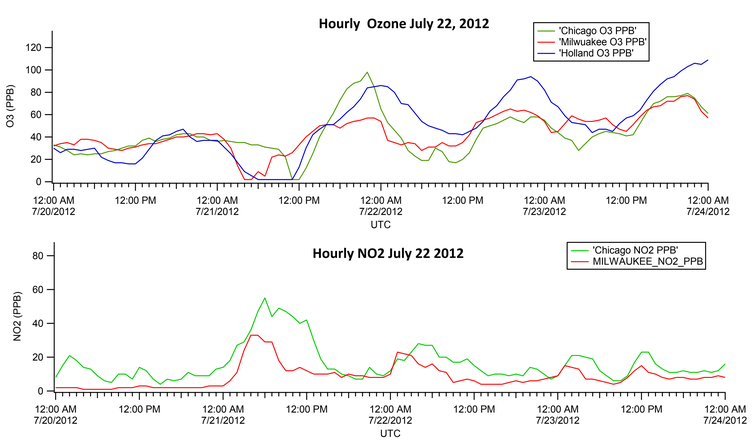


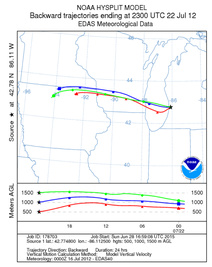
EDAS Backward Trajectory July 16,2012



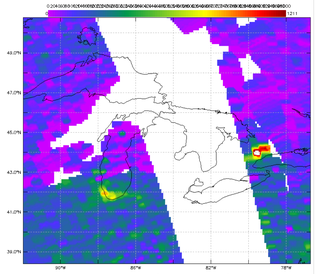
OMI Tropospheric Column NO_2 July 16, 2012

July 22, 2012 Ozone Event





EDAS Backward Trajectory July 22,2012



OMI Tropospheric Column NO_2 July 22, 2012

Shown to the left are the ozone, NO_2, and trajectory data for two Holland, MI ozone events that occurred in July of 2012.

Notice that in both cases, the ozone levels in western MI (Holland) at times exceed those in both Chicago and Milwaukee. It is interesting to note that the ozone peaks in all three cities seem to occur nearly simultaneously, which would seem unlikely if the elevated ozone in Holland was due entirely to transport over Lake Michigan. The transportation process would take time as the air mass drifted over the lake, causing the Michigan peaks to be delayed from the Chicago peaks. However, there is almost certainly some transport of ozone into Michigan from these two cities as indicated by the EDAS trajectory data.

The timescale for the ozone profile in Holland to begin to elevate after the peak NO_2 is reached in Chicago and Milwaukee is consistent with the travel time of the air mass over the lake. This would be consistent with the occurrence of ozone chemistry over the lake. Such speculation would benefit from statistical analysis as well as atmospheric sampling over the lake or minimally, NO_2 data in western Michigan.

Conclusions

Western Michigan suffers an ongoing problem with elevated ozone levels despite a relative lack of likely anthropogenic sources. Unless some other source is identified, ozone data does seem to support an influence from major industrial centers outside of the state of Michigan. It is likely that transport takes place across the lake of both ozone and its precursors. This leaves open the possibility that nitrogen oxides and volatile organics are undergoing photochemical transformation into ozone while moving over the lake.

References

1. Seinfeld JH. 1989. Urban air pollution: state of the science. *Science **243: 745–752.***
2. LENNARTSON, G. J. (2002). THE Lake Breeze–Ground Level Ozone Connection . *INTERNATIONAL JOURNAL OF CLIMATOLOGY* , 1347–1364.
3. SANFORD Srl I•MAN, P. J. (1993). Ozone Production in Urban Plumes Transported Over Water. *JOURNAL OF GEOPHYSICAL RESEARCH,* , 687-699.

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